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for

A HIGH ISOLATION DUAL POLARIZED ANTENNA SYSTEM USING DIPOLE RADIATING ELEMENTS

by

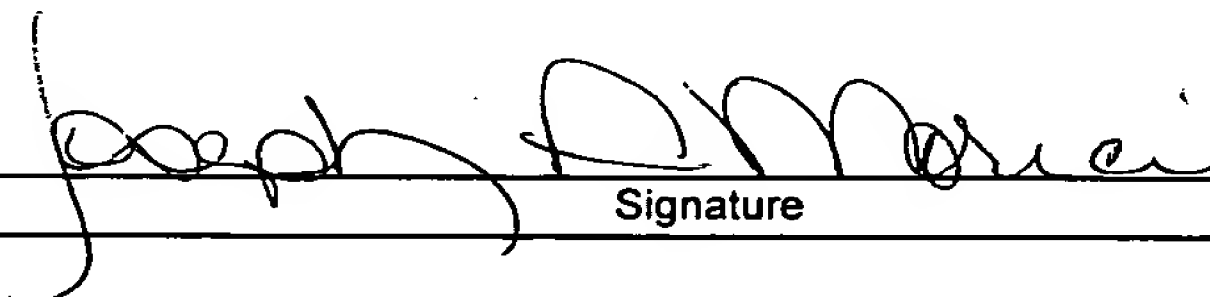**Ronald J. Brandau**

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A HIGH ISOLATION DUAL POLARIZED ANTENNA
SYSTEM USING DIPOLE RADIATING ELEMENTS

<u>BACKGROUND OF THE INVENTION</u>

Base stations used in wireless telecommunication systems have the capability

5   to receive linear polarized electromagnetic signals. These signals are then processed

by a receiver at the base station and fed into the telephone network. In practice, the

same antenna which receives the signals can also be used to transmit signals if the

transmitted signals are at different frequencies than the received signals.

A wireless telecommunication system suffers from the problem of multi-path

10   fading. Diversity reception is often used to overcome the problem of severe multi-

path fading. A diversity technique requires at least two signal paths that carry the

same information but have uncorrelated multi-path fadings. Several types of diversity

reception are used at base stations in the telecommunications industry including space

diversity, direction diversity, polarization diversity, frequency diversity, and time

15   diversity. A space diversity system receives signals from different points in space

requiring two antennas separated by a significant distance. Polarization diversity uses

orthogonal polarization to provide uncorrelated paths.

As is well-known in the art, the sense or direction of polarization of an antenna

is measured from a fixed axis and can vary, depending upon system requirements. In

20   particular, the sense of polarization can range from vertical polarization (0 degrees) to

horizontal polarization (90 degrees). Currently, the most prevalent types of

polarization used in systems are those which use vertical/horizontal and +45°/-45°

polarization("slant 45°"). However, other angles of polarization can be used. If an

antenna receives or transmits signals of two polarizations normally orthogonal, they

25   are also known as dual polarized antennas.

An array of slant 45° polarized radiating elements is constructed using a linear

or planar array of crossed-dipoles located above a ground plane. A crossed dipole is a

pair of dipoles whose centers are co-located and whose axes are orthogonal. The axes

of the dipoles are arranged such that they are parallel with the polarization sense

required. In other words, the axes of each of the dipoles is positioned at some angle with respect to the vertical axis of the antenna array.

One problem associated with such a configuration is the interaction of the electromagnetic field of each crossed dipole with the fields of the other crossed

5   dipoles and the surrounding structures which support and house the crossed dipoles. As is well known in the art, the individual electromagnetic fields surrounding the dipoles transfer energy to each other. This mutual coupling or leakage influences the correlation of the two orthogonally polarized signals; the amount of coupling is often referred to as "isolation." The isolation between orthogonally polarized signals is

10   preferably -30 dB or less.

The visual impact of base station towers on communities has become a societal concern. It has become desirable to reduce the size of these towers and thereby lessen the visual impact of the towers on the community. The size and scale of the towers can be reduced by using base station towers with fewer antennas. This

15   can be achieved if dual polarized antennas and polarization diversity are used. Such systems replace systems using space diversity which require pairs of vertically polarized antennas. Some studies indicate that, for urban environments, polarization diversity provides an equivalent signal quality as space diversity. With the majority of base station sites located in urban environments, it is likely that dual polarized

20   antennas will be used in place of the conventional pairs of vertically polarized antennas.

SUMMARY OF THE INVENTION

It is a principle object of the invention to provide an antenna array comprised of dual polarized radiating elements which are used to receive signals for a polarization

25   diversity receiver.

It is a further object of the invention to provide an antenna array where the radiating elements are comprised of crossed-dipole elements.

It is another object of the invention to provide an antenna array which improves isolation between the sum of one set of like-polarized signals and the sum of the orthogonal set of polarized signals;

It is yet another object of the invention to provide an antenna that minimizes the number of antennas required thereby providing an aesthetically pleasing structure that is of minimum size and scale.

It is still another object of the invention to provide an array of radiating elements where electrical "downtilt" is used.

These and other objects of the invention are provided by an improved antenna system comprising an array of radiating elements, the array having a length and placed on a ground plane and having a vertical axis along its length, the array comprising a plurality of dipole radiators, said radiators comprised of first and second crossed dipoles, said dipoles aligned at a predetermined angle with respect to said vertical axis, said radiating elements producing first electromagnetic fields; a plurality of supports, said supports perpendicular to said vertical axis and placed between selected of said plurality of dipole radiators; a plurality of metallic parasitic elements placed in a selected of said plurality of supports, said first electromagnetic fields exciting currents in said metallic parasitic elements, said currents creating second electromagnetic fields, said second electromagnetic fields canceling with said first electromagnetic fields.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

FIG. 1 is a block diagram of the overall system which utilizes antennas according to principles of the present invention;

FIG. 2 shows a perspective view of an array of receivers together with the parasitic elements according to principles of the present invention;

FIG. 3 shows a top view of the array of FIG. 2 according to principles of the present invention;

FIG. 4 is an end view of the array of FIG. 2 according to principles of the present invention;

FIG. 5 is a top view showing de-coupling rods used as parasitic elements according to principles of the present invention;

FIG. 6 is an end view showing de-coupling rods used as parasitic elements according to principles of the present invention;

FIG. 7 is a top view showing de-coupling rods used as parasitic elements according to principles of the present invention; and

FIG. 8 is an end view showing de-coupling rods used as parasitic elements according to principles of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1, a user with a cellular phone 4 transmits an electromagnetic signal to a base station 5. The base station 5 comprises a plurality of antennas 6a, 6b, 6c, and 6d connected to a platform 6e. As discussed below, each antenna comprises a plurality of crossed (co-located, orthogonal) dual dipole radiating elements. Alternatively, the antennas can be connected to a tower 7. The platform 6e is coupled to a tower 7 which elevates the antennas above surrounding buildings and other obstructions. The received signals pass over a plurality of transmission lines 8a, 8b, 8c, and 8d to a base station processing system 3 which includes a diversity receiver 9. From the base station processing system 3, the processed signals are transmitted over land phone lines and into the telephone network using equipment and techniques which are well known to those skilled in the art.

Referring now to FIGs. 2-4, an array (antenna) 10 of crossed, dual-polarized dipole radiating elements 11a, 11b, 11c, and 11d are connected to a ground plane 12. The composition and dimensions of the radiating elements 11a, 11b, 11c, and 11d and the ground plane 12 determine the radiation characteristics, beam width, and the impedance of the radiating elements. Preferably, the radiating elements 11a, 11b, 11c, and 11d and the ground plane 12 are composed of some metal such as aluminum.

However, other metals can be used to construct the radiating elements and the ground plane 12 such as copper or brass.

It will be understood by those skilled in the art that the gain of the antenna is proportional to the number of spaced radiating elements present in the array. In other

5   words, increasing the number of radiating elements in the array increases the gain while decreasing the number of radiating elements decreases the antenna's gain. Therefore, although only four radiating elements are shown, the number of radiating elements can be increased to any number to increase the gain. Conversely, the number of radiating elements can be reduced as required thereby reducing the gain.

10   The radiating elements 11a, 11b, 11c, and 11d transmit and receive electromagnetic signal transmissions and are comprised of pairs of dipoles 14a and 14b, 16a and 16b, 18a and 18b and 20a and 20b, respectively. The dipoles comprising the radiating elements 11a, 11b, 11c, and 11d are crossed and configured with 45 degree slant angles (with respect to the axis of the array 13). That is, the axes of the

15   dipoles are arranged such that they are parallel with the polarization sense required. As shown, the slant angles $+\alpha$ and $-\alpha$ are +45 degrees and -45 degrees, respectively. Although shown with slant angles of +45 degrees and -45 degrees, it will be understood by those skilled in the art that these angles can be varied to optimize the performance of the antenna. Moreover, each angle need not be identical in

20   magnitude. For example, $+\alpha$ and $-\alpha$ can be +30 degrees and -60 degrees, respectively.

Each of the radiating elements 11a, 11b, 11c, and 11d receive signals having polarizations of +45 degrees and -45 degrees. That is, one dipole in the radiating element receives signals having polarizations of +45 degrees while the other dipole

25   receives signals with polarizations of -45 degrees. The received signals from parallel dipoles, 14a, 16a, 18a, 20a or 14b, 16b, 18b, and 20b, are combined using a feed network (not shown) for each polarization. The feed network is composed of coaxial, microstrip, stripline, or other transmission line structures. The two combined signals are fed to a diversity receiver which chooses the strongest amongst these two signals

30   for further processing. Each of the radiating elements 11a, 11b, 11c, and 11d can also

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act as a transmitter provided that the transmitted signal is at a different frequency than the received signal.

A parasitic element 22 is placed on a support 24. In order to be non-conducting, the support is comprised of polyethylene foam. However, other suitable

5   non-conducting materials such as other non-conducting plastics or foams can be substituted for polyethylene foam and used for construction of the support 24. The support 24 is first formed and attached to the back plane 12. A groove is then cut into the support 24 into which the parasitic element 22 is inserted.

In order for currents to be induced, the parasitic element 22 is formed of metal.

10   This metal is preferably aluminum, although other metals such as copper or brass can also be used. A primary electromagnetic wave or field incident upon the array structure induces currents on the surfaces of the crossed dipoles of each of the radiating elements of the array, the parasitic elements, and the surrounding metal structure. These induced currents create a weaker secondary electromagnetic field

15   which will combine with the primary electromagnetic field. A state of equilibrium will occur such that the final electromagnetic field is different from the primary electromagnetic field. The dimensions and positions of the parasitic elements are a factor in determining the final field. In other words, the improved isolation of the present invention is achieved by currents excited on the parasitic elements which re-

20   radiate energy that cancels the energy which couples from one polarization to the other causing the isolation to be at a minimum.

The parasitic elements are placed halfway between the crossed dipole radiating elements of the array and are perpendicular to the axis 13 of the array. However, parasitic elements are not necessarily placed in between every element of the array. A

25   network analyzer is used to determine the optimum number and positioning of the elements. In particular, the network analyzer is employed such that the isolation of any given configuration of radiating elements and parasitic elements can be measured. The length of the parasitic elements controls the magnitude of the current produced. For example, with the length at approximately one-half a wavelength, the maximum

amount of current is produced. Thus, the performance of the system can also be optimized by changing the length of some or all of the parasitic elements.

Positioning the parasitic element above the top of the crossed dipoles has been found to optimize isolation for this array configuration. However, the height of

5   placement of the parasitic element can vary depending on the array configuration.

The parasitic elements are situated so as to cause no undue side effects such as degradation of the return loss (VSWR) nor do the parasitic elements unduly disturb the normal array radiation patterns. It has been found that optimum antenna performance occurs when the parasitic elements are placed parallel to or perpendicular

10   to the vertical axis of the array. Placing the parasitic elements at other angles with respect to the vertical axis of the array has been found to detrimentally affect antenna performance. As discussed above, a network analyzer is used to determine when isolation improves and radiation patterns measured confirm to pattern performance.

In an illustrative embodiment of the configuration of FIG. 2, four crossed-

15   dipole antennas were placed on a ground plane 480 mm long by 150 mm wide to operate in the PCS/N band of frequencies which is 1710-1990 MHz. The vertical axis 13 of the array stretched along the 480 mm length. Four dual polarized, crossed-dipole radiating elements were used. The first radiating element was placed 60 mm from the edge, the second element was placed 120 mm from the first element, the

20   third 120 mm from the second element, and the fourth 120 mm from the third element. The elements were aligned along the vertical axis of the array having slant angles of +45 degrees and -45 degrees with respect to the vertical axis 13 of the array.

Two supports were situated 120 mm from the edges of the ground plane and perpendicular to the vertical axis of the array. The supports were 75 mm tall and had

25   a thin, rectangular parasitic element placed on top. The parasitic element was 5 mm wide and 150 mm long. The parasitic elements were placed at the top of the support and extended along the full length of the support.

Referring now to FIGs. 5 and 6, an array 210 of crossed, dual-dipole radiating elements 202, 203, and 204 are attached to a ground plane 201 to operate in the

30   cellular band of frequencies of 820-960 MHz. As discussed above, the composition

and dimensions of the ground plane 201 and the radiating elements 202, 203, and 204 determine the radiation characteristics, beam width, and the impedance of the antennas.

5   The radiating elements 202, 203, and 204 transmit and receive electromagnetic signal transmissions and are comprised of pairs of dipoles, 211a and 211b, 212a and 212b, and 213a and 213b, respectively. The dipoles comprising the radiating elements 202, 203, and 204 are crossed and configured with 45 degree slant angles (with respect to the axis of the array 215). That is, the axes of the dipoles are arranged such that they are parallel with the polarization sense required. As shown, the slant

10   angles $+\alpha$ and $-\alpha$ are +45 degrees and -45 degrees, respectively. Although shown with slant angles of +45 degrees and -45 degrees, it will be understood by those skilled in the art that these angles can be varied to optimize the performance of the antenna. A front side wall 207 and rear side wall 208 contribute to the radiation characteristics of the antenna.

15   Each of the radiating elements 202, 203, and 204 receive signals having polarizations of +45 degrees and -45 degrees. The received signals from parallel dipoles 211a, 212a, and 213a, or 211b, 212b, and 213b, are combined using a feed network for each polarization. The feed network is composed of coaxial, microstrip,, stripline, or other types of transmission lines. A diversity receiver connected to the

20   antenna then chooses the strongest amongst these two combined signals for further processing. Each of the elements 202, 203, and 204 can also act as a transmitter provided that the transmitted signal is at a different frequency than the received signal.

A parasitic element 205 is supported and elevated by pairs of rod supports 206a and 206b. The parasitic element preferably acts as a de-coupling rod. The

25   parasitic element is perpendicular to the vertical axis 215 of the array. The rod supports are constructed of a non-conducting material. Although one parasitic element is shown, it will be understood that the exact number of parasitic elements can be varied and depend upon the exact configuration and other required characteristics of the antenna.

Referring now to FIGs. 7 and 8, an array 310 of crossed, dual-dipole radiating elements 302, 303, and 304 are connected to a ground plane 301 to operate in the cellular band of frequencies of 820-960 MHz. As discussed above, the composition and dimensions of the ground plane 301 and radiating elements 302, 303, and 304

5   determine the radiation characteristics, beam width, and the impedance of the antennas.

The radiating elements 302, 303, and 304 transmit and receive electromagnetic signal transmissions and are comprised of pairs of dipoles, 311a and 311b, 312a and 312b, and 313a and 313b, respectively. The dipoles comprising the radiating

10   elements 302, 303, and 304 are crossed and configured with 45 degree slant angles (with respect to the axis of the array 315). That is, the axes of the dipoles are arranged such that they are parallel with the polarization sense required. As shown, the slant angles $+\alpha$ and $-\alpha$ are +45 degrees and -45 degrees, respectively. Although shown with slant angles of +45 degrees and -45 degrees, it will be understood by those

15   skilled in the art that these angles can be varied to optimize the performance of the antenna. A front side wall 307 and rear side wall 308 contribute to the radiation characteristics of the antenna.

Each of the radiating elements 302, 303, and 304 receive signals having polarizations of +45 degrees and -45 degrees. The received signals from parallel

20   dipoles 311a, 312a, and 313a or 311b, 312b, and 313b, are combined using a feed network for each polarization. The feed network is composed of coaxial, microstrip, stripline, or other type of transmission line. A diversity receiver connected to the antenna then chooses the strongest amongst these two combined signals for further processing. Each of the elements 302, 303, and 304 can also act as a transmitter

25   provided that the transmitted signal is at a different frequency than the received signal.

A first parasitic element 305a is supported and elevated by rod supports 306a and 306b. The parasitic element 305a is parallel to the vertical axis 315 of the array. Additionally, a second parasitic element 305b is supported and elevated by rod supports 306c and 306d. The parasitic element 305b is also parallel to the vertical

30   axis 315 of the array and acts as a de-coupling rod. The rod supports are constructed

of non-conducting material. Although two parasitic elements are illustrated in this embodiment, it will be understood that the number can be varied according to the exact configuration and operating characteristics of the array.

Thus, an antenna array is provided which is comprised of dual polarized radiating elements and produces two orthogonally polarized signals. Furthermore, the invention provides an antenna array where the antennas are comprised of crossed-dipole elements and which improves isolation between the electromagnetic fields of the crossed dipole elements. An antenna has also been provided which minimizes the number of antennas required in a wireless telecommunication system thereby providing an aesthetically pleasing structure that is of minimum size and scale.

While the present invention has been described with reference to one or more preferred embodiments, those skilled in the art will recognize that many changes may be made thereto without departing from the spirit and scope of the present invention which is set forth in the following claims.